Acceptance speech for the John Martin Award, February 2007
Robin L. Vannote

The Pathway to an Idea: A River System as a Continuum

The authors of the River Continuum Concept (RCC) are certainly honored to have their paper receive this prestigious award from the American Society of Limnology and Oceanography. The John Martin award is recognition of our team effort to provide a conceptual model for a stream ecosystem and its watershed. Since its conception in the mid seventies and publication in 1980, the hypothesis that a river system operates as a continuum, where structure and function are strongly linked to hydro-geologic and biotic properties of watersheds has been widely tested. The initial concept was further strengthened by additional results from cross biome comparisons and a major group study of the 8th order Salmon River (Minshall *et. al.*, 1983, 1992). Subsequent studies and critiques by many ecosystem scientists have led to further development of the concept. The central idea continues to evolve as new knowledge is added about energy flow to higher trophic levels, the complex structure of dissolved organic compounds, and the interplay between autochthonous and terrestrially derived organic matter along a river course. A recent review by Cummins *et. al.* (2006) documents changes that have been incorporated into the initial theory by two decades of research, as well as discussing conceptual models proposed by others and outlining areas of research for the future.

Rather than examine and comment on an array of research findings that support the RCC or suggest alternatives models, I thought it might be of interest to trace personal major pathways and experiences that played a formative role in the development of the ideas that led to the central hypothesis of the RCC. I feet I was most fortunate, in that my career path intersected with excellent professors, unique research opportunities, colleagues at the Stroud Center dedicated to team research, and other very talented scientists, notably, G. Evelyn Hutchinson, Herbert H. Ross, and Luna B. Leopold. Working in this collaborative environment fostered discussion and generation of new ideas. Today, many ecosystem scientists and students enjoy the benefits of enthusiastic professors, long term, team-based research, and international collaboration. This mix (and adequate funding) is crucial for meeting research goals and addressing global challenges.

Limnology captured my interest and set my career path while still in high school, when I discovered a 1930 edition of *Life of Inland Waters* (Needham and Lloyd) and a 1931 book about trout streams on my father's bookshelf. He had taken J. G. Needham's limnology course at Cornell (Needham and Lloyd were first generation limnologists). The latter, Edward R. Hewitt's *Better Trout Streams,* dealt with stream improvement devices for Catskill streams which were highly impacted during an early 1900's logging cycle in eastern forests. Fascinated by the subject matter, my future career path was set.

Entering a fisheries and wildlife curriculum at the University of Maine, I was strongly guided and encouraged by Prof. W. Harry Everhart in the classroom, through summer employment and by a special problem assignment. For this, Dr. Everhart handed me a data set on population structure for brook and brown trout and said "If you will study Saul Saila's recent article in *Limnology and Oceanography* (1956:Vol.1), then calculate a minimum size-limit for trout in Maine, I'll give you two course credits". This project introduced me to mathematical approaches to population dynamics, as well as to a brand new journal, *L &O* (with H. T. Odum's article on primary production) and E. P. Odum's book *Fundamentals of Ecology.* Two summers of electro-fishing salmon tributaries in the Machais and Penobscot drainages afforded me a great learning experience. This project also revealed the enormous challenges involved in trying to protect and reestablish salmon runs in a state running on a pulp and paper economy. A memorable highlight was knifing into the gut of an engorged eel tossed onto the Pleasant River bank and seeing, by count, about 250 silvery alewives spill onto the grass. I thought "wow, a catadromous-anadromous conflict" and became hooked on food chains.

Dr. Everhart urged to me consider graduate schools. Fortunately, I was accepted by Robert C. Ball (a Paul Welch student) at Michigan State University, who had already fully embraced the Lindeman and Odum model for studying energy flow and nutrient cycling in open aquatic ecosystems. As part of Dr. Ball's program, I developed a phosphorus input and transport budget for the Red Cedar River and tributaries. For a dissertation, I measured energy and organic matter flow from producers to crayfish to small-mouth bass, using Odum's and John E. Teal's approach. The energy flow was largely from detritus to crayfish to bass, with population densities controlled by silt, sand and sewage effluent.

After receiving my degree, I was hired by TVA to start a limnological study of the TVA reservoir system and to determine if warm water discharge from the Paradise Steam Plant

affected the Green River in central Kentucky. (It did). Working under the direction of engineers, I quickly learned it was necessary to understand the hydraulic dynamics of the system before collecting and interpreting biological data. The studies focused on benthic communities and plankton production in a large river-reservoir system. However, still remaining attracted to small streams, I became an enthusiastic member of Herb Ross's "winter stonefly club" and scoured leaf-choked streams for specimens and became intrigued by leaf-pack communities. This was a start to a long and intellectually stimulating association with Dr. Ross.

In 1966, Ruth Patrick (ANSP) invited me to establish a stream ecology laboratory in rural Chester County, PA. I welcomed this challenge to initiate a research program geared to my special interests. The two topics at the top of my research list were the trophic dynamics of filter feeding caddis flies and leaf litter; its input, processing and transport. I wrote up a proposal and took it to the Academy for Dr Patrick's approval. To my complete surprise, she had invited G. Evelyn Hutchinson to the review. Fortunately, he enthusiastically supported my proposal to quantify the trophic dynamics of allochthonous detritus in woodland streams. Thus, by mid October of that year, thirty "lunch pail" size poultry wire cages, stocked with 25g of leaves, were placed in White Clay Creek (WCC) along with 30 fall-in trays (0.5 sq. m) and a weir to estimate transport.

At the new research facility, the Stroud Center, the scientific staff, the scope of studies and a teaching program expanded rapidly with a focus on team-based research. Colleagues included Tom Bott, working on microbial processes and community metabolism, Rick Larson, focused on transformation and photo-oxidation of soluble organic compounds and Ruth Patrick, who studied diatom diversity. My own work centered on the dynamics of consumer organisms, detrital processes and vegetative control of channel morphology. The small interactive group created an ideal setting to develop new ideas about stream ecosystems and watershed processes. Although our proposal for an ecosystem study of WCC failed to get IBP support, it was funded by the Rockefeller Foundation for a 4-year period.

My constantly growing interest in coupling stream ecosystem dynamics and fluvial geomorphology was spurred by several events. In the fall of 1969, Luna Leopold (Chief of the Hydraulic Data Division USGS at that time) brought several chemists and hydro-geologist to the Academy to learn methods for measuring biotic diversity at gaging stations. The Stroud Center and area streams were used for the session, giving me the opportunity to become acquainted with

Dr. Leopold. At Dr. Patrick's request, he began a long-standing participation in our team taught limnology course, lecturing on the construction of flood frequencies curves for WCC and identification of floodplain boundaries. Over several decades, both Leopold and Hutchinson frequented the Stroud Center and gave valued advice and critiques of our research and ideas. Some of my fondest memories are of discussions of community and ecosystem evolution with Dr. Ross.

In the early 1970s, I had an opportunity to study the biological impact of channelization on forty streams and rivers spread across the United States as part of a CEQ program to evaluate the cost benefits and environmental impact of USACE, SCS (NRCS) and BLM projects. Watersheds ranging from sections of the Kissimmee, the Rio Grande and Kings rivers to prairie headwater tributaries, bayous, and rural and urban streams were included. The comparison of channeled streams to nearby undisturbed controls clearly demonstrated the validity of the dynamic equilibrium concepts proposed by Leopold and others over the previous decade. It was evident that the constant reworking of entrained sediment in over-sized channels, the drainage of adjoining wetlands and a disconnect with the forest ecosystem limited biotic communities to fragmented patches where stream beds were stable. These experiences inspired me to further delve into a vast literature on stream geomorphology.

At the conclusion of our WCC studies in 1973, the Rockefeller Foundation suggested that we hold a meeting at Center to bring together scientists from aquatic research sites in the eastern U.S. to present our research finding. Word of the autumn meeting spread and the number of attendees doubled. Near the end of the meeting, Jim Sedell asked "What is next after IBP? That winter, a group, including Jim, Wayne Minshall, Ken Cummins and Bert Cushing, met at the Kellogg Biological Station to formulate ideas for a collaborative cross biome study and in the spring of 1974, a larger group gathered at the Stroud Center to further define the project. At this diverse interdisciplinary meeting, we struggled to agree on methods and a central theme.

Approaching a stalemate, I suggested an entirely new approach. I had recently recast the WCC data into a continuum concept, strongly linked to the fluvial geomorphic properties of the watershed. Our original model based on energy flow per unit area had failed to provide for the continuous biological adjustments to seasonal changes in loading, transport, and utilization of energy. The seasonal patterns suggested a balance between a tendency to use energy efficiently and an opposing tendency for uniform rate of energy processing. The trade off is energy leakage

upon which downstream communities are partially structured. Early in the study, we found that fluvial geomorphic processes operating throughout the drainage network were a major factor in structuring habitat, establishing community structure and regulating the distribution and storage of organic matter. The concept of river continuum came about by coupling the dynamics of the physical system to a large empirical data set based on community structure and function in the 3rd order WCC. Trajectories for various system parameters (*e.g.* P/R ratio) were projected to higher order streams based on seasonal measurements of phytoplankton production (LB/DB) and benthic community structure at a number of TVA river and reservoir sites, the literature and a comparative study of channelized and natural streams.

The group embraced this "river continuum" concept as a way to make biome comparisons of stream structure and function and to test the continuum concept on 1st to 5th order streams. Subsequent meetings were held at Kellogg, Oregon State and Idaho State Universities to design the study, write an NSF proposal and collaborate on producing a manuscript describing the model.

Although the RCC proved to be an influential conceptual model for studying energy flow in fluvial ecosystems at many scales, initial publication of the theory did not flow smoothly. First submitted to *BioScience* in 1978, the manuscript was rejected with a reviewer's comments, "capricious and unpredictable." With significant contributions by Wayne, Ken, Jim and Bert, a revised version was submitted in 1979 to *The America Naturalist*. The paper was summarily rejected without outside review. While the editor wrote "*The American Naturalist* welcomes manuscripts that attempt new theoretical syntheses, especially in combination with new empirical information of broad significance", the assistant editor commented, "I do not feel this paper poses a hypothesis that can be tested." and "specific hypothesis must be suggested for streams. For now, it just seems too diffuse." The manuscript was then submitted to the *Canadian Journal of Fisheries and Aquatic Sciences,* where it was enthusiastically accepted. The paper, now with over 1800 citations, became a "Citation Classic" in within nine years (a record at that time). The project, funded by NSF, subsequently resulted in 33 additional publications.

Collaboration within the group has continued to the present. Over the years, I have derived much personal satisfaction from my interaction with so many outstanding scientists and students. For Wayne, Ken, Jim and Bert and myself, I sincerely thank ASLO and the individuals who

nominated our paper. We are honored and gratified that it was selected to receive the John Martin Award.

X-Sieve: CMU Sieve 2.3
Date: Sun, 3 Jun 2007 11:25:53 -0700 (PDT)
From: "Vincent H. Resh" <vresh@nature.berkeley.edu>
To: Cheryl Haigh Resh <cherylresh@calmail.berkeley.edu>
Subject: Re: RCC archive (fwd)
X-Virus-Scanned: Maia Mailguard 1.0.2

Can you please print these out for me?
Love ya
V

---------- Forwarded message ----------
Date: Mon, 28 May 2007 12:57:55 -0400
From: Robin Vannote <rlvann34@msn.com>
To: Vincent H. Resh <vresh@nature.berkeley.edu>
Subject: Re: RCC archive

Dear Vince,
I certainly owe you a great deal of thanks for suggesting to the ASLO awards committee our river continuum paper for the Martin Award. I greatly enjoyed presenting the paper at ASLO's Santa Fe meeting in February. It was enthusiastically received, getting a loud round of applause about midway through and at the end. I gave the presentation from two pages of hand written notes and injected humor along the way to keep it a little light. Jerry and I attended quite a few of the sessions and really enjoyed the week.
Again, Thanks!
I am attaching both the manuscript submitted to ASLO and copy of the power point slides used to support the talk. Let me know if they come over to you okay.
Best wishes, Robin
----- Original Message -----
From: Vincent H. Resh<mailto:vresh@nature.berkeley.edu>
To: rlvann34@msn.com<mailto:rlvann34@msn.com>
Sent: Monday, May 21, 2007 5:18 PM
Subject: RCC archive

Dear Robin
I hope that this message finds you well.
In trying to keep all the RCC material together based on the interviews we held out here, would you have a copy of the talk you gave at ASLO in February that I could add to these materials?
Thanks.
Vince

 The Pathway to an Idea 07.doc

 ASLO PP presentation 07.ppt